Dielectric Spectroscopy and Charge Storage Mechanism of Polymeric Materials

Proposal for Ph.D.

on

Submitted by

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Introduction

A strong industrial interest in electrical properties of polymers reflects the growing use of these materials in electronic interconnect devices, optoelectronic switches, printed board circuitry, microwave assemblies for radar, batteries, fuel cells and so on. There are very good reasons for the current surge of interest in fundamental and applied aspects of dielectric spectroscopy (DS) of polymeric materials. Fundamental investigation of dielectric response yields a wealth of information about different molecular motions and relaxation processes. A unique characteristic of DS is the wide frequency range, from 10^{-5} Hz to 10^{11} Hz over which polymer respond to an electric field. This remarkable breadth of frequency range is the key feature that enables to relate the observed dielectric response to slow frequency and fast high frequency molecular events.

Polymeric electrets are complex systems. In today's world of sophisticated mechanical, electromechanical and electronic applications, polymeric electrets are playing an increasingly important part. The most significant advantage of studying the charge storage mechanism of polymeric electrets is their complex structure, which can be physically or chemically tailored for specific applications. The study of charge storage mechanism has become indispensable not only for the quality control of existing electrets, but also for the development of better electrets and charging methods. The information about the charge storage mechanism gives a piece of the picture to understand the charge-retention mechanisms. Moreover, this information helps to identify the probable trapping sites and to explain how the long-term storage happens. The principal goal of this work is to study the charge storage mechanisms of polymeric electret with the help of Dielectric spectroscopy and thermally stimulated current (TSDC) technique.

Experimental Technique

When the polymeric material is exposed to an external excitation (like the electric field and temperature), the orientation of permanent dipoles (in polar materials), trapping of charges and their interactions are merged in the overall electrical response. In dielectric spectroscopy technique, the dielectric permittivity as well as the losses are measured as a function of frequency and temperature with the help of LCR meter. Dynamic processes from dipoles and charge carriers as kinetics and interactions are merged in a signal plotted against the frequency and temperature. These dynamic processes can be identified by their characteristic frequency of relaxation.

The TSDC method is based on the depolarization of a sample by thermal activation. The depolarization current, when the temperature is increased at a constant rate, exhibits a series of maxima, which correspond to the different thermal transitions. In this technique, which is also known as the temperature-dependent TSDC method, the sample is polarized by externally applied electric field and temperature. The varying poling time, which is much longer than the relaxation time, models the aging period of the specimen. Subsequently, this polarization is frozen-in by cooling the sample in the presence of the applied electric field to room temperature such that the frozen-in polarization remains unchanged, even if the external field is switched off. By heating the sample at a constant rate, the depolarization current, as the polarizing specimens relax, is detected by a high sensitive electrometer. The decay processes are investigated as a function of temperature. The yielded information gives the trace to identify the charge storage mechanism of polymeric electret.

Literature Review

The analysis of dielectric dielectric relaxation on main chain thermotropic liquid crystalline Copolyesteramide was carried out by ***Boersma et al (1998). Quamara et al (2001)*** studied the dielectric relaxation processes in poly (*p*-phenylene sulfide) using a thermally stimulated discharge current technique. ***Neagu et al (2002)*** reported the polarization and space charge analysis in thermally poled PVDF. ***Khare et al (2004)*** investigated the depolarization of polyvinylidene fluoride foil electrets. Shaoung et al (2005) investigated charge storage in nitrided nanocrystalline silicon dots. Dielectric relaxations in ultrathin polystyrene layers were studied by ***Lupascu et al (2005).*** Dielectric properties of industrial polymer composite materials were studied by ***Akram et al (2005).*** Dielectric Spectroscopy was taken as a probe for studting the dynamic properties of compacted smectites by A Cadene et al. Dielectric spectroscopy studies on (PVP + PVA) polyblend film were reported by ***Subba Reddy (2006). Meier and Klüppel (2007)*** analyzed the morphological structure of carbon black (CB) networks in elastomers and their flocculation dynamics under heat treatment and especially during vulcanization by dynamic mechanical and dielectric spectroscopy.

Multiple relaxation investigations in polyetherimide: Thermally stimulated depolarization current was reported by ***Singh et al (2008).*** Thermally stimulated depolarization current and dielectric relaxation spectroscopy in poly (vinylidene fluoride) samples were reported by ***Shukla et al (2008).*** High-resolution isothermal dielectric spectroscopy was reported as a function of frequency up to 10^5 Hz and electric field on four carbon allotropes; amorphous glass, diamond, multiwall nanotubes (MWNTs), and single-wall nanotubes (SWNTs) by ***Basu and Iannacchione (2008).*** The effects of the concentration of La^{3+} on the morphology and dielectric properties of the prepared samples were investigated by ***Ai (2008).***

Introduction to the Problem

Though chemical and physical characteristics of polymers have been identified to affect the dielectric properties of the polymeric electrets, microscopic mechanisms of charge retention are still poorly understood. In this work, the combination of dielectric spectroscopy and TSDC technique is proposed in order to describe the charge trapping and detrapping, behaviour of a polymeric electret. Dielectric spectroscopy can provide information about the segmental mobility of a polymer by probing its dielectric properties. TSDC has been vital in setting up the criteria that materials must fulfill if reliable technical electrets are to be made from them. Its main task in electret research is to arrive at detailed information about deep traps in dielectrics able to hold charges captive for a prolonged period at room temperature.

The present investigation will be undertaken in effort to augment the earlier study by investigating dielectric loss and charge storage mechanism of polymeric samples by means of dielectric spectroscopy and TSDC technique.

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